

## Empirical Application

### Data Sources

The model developed in the last section is used to formulate a price-forecasting model for the consumer prices of 16 food categories as defined in the structure of Consumer Price Indexes (CPI). These food categories are (1) beef and veal, (2) pork, (3) other meats, (4) poultry, (5) fish and seafood, (6) eggs, (7) dairy products, (8) fats and oils, (9) fresh fruits, (10) fresh vegetables, (11) processed fruits and vegetables, (12) sugar and sweets, (13) cereals and bakery products, (14) nonalcoholic beverages, (15) other prepared foods, and (16) food away from home. The price data for these food categories come from the annual *Consumer Price Index* from 1980 to 1997 (U.S. Department of Labor). Per capita total expenditures to represent the income variable are computed by dividing the personal consumption expenditures (obtained from the U.S. Department of Commerce) by the civilian population of 50 States on July 1 of each year.

The quantity data are compiled from *Food Consumption, Prices, and Expenditures* (Putnam and Allshouse, 1999). Most of the food quantities are measured in retail weight. For example, the quantities of red meats are measured in retail cut equivalent. The quantity of poultry is measured in boneless trimmed equivalent. The quantities of dairy products are measured in milk equivalent on milkfat basis. Some quantity data of food categories cannot be constructed to match the price indexes defined by the CPI. For example, wheat food use was tried as a quantity proxy in the equation for cereals and bakery products but was not satisfactory in fitting the demand equation. One reason is that wheat is only one farm-level ingredient in cereals and bakery products, so the farm-level quantity is probably not representative of the retail quantity. Another reason is that the farm value represented by the wheat quantity measure is a small share of the retail product value of cereals and bakery products.

Given the difficulty of defining a pairwise price-quantity for individual food categories, the aggregated quantities consisting of six food groups (red meats, poultry, dairy, fruits and vegetables, starchy foods, and other foods) are used as proxy explanatory variables for each price equation. These aggregate quantities for each food group are calculated as the Laspeyres indexes from a total of 143 individual food items. For explaining price changes of those food categories without explicitly defined quantities of own category

as an explanatory variable in the model, cross-quantity effects and per capita income are considered major determinants. For example, the price variations of the other meats category are likely captured or represented by per capita income and the cross-quantity effects with red meats and poultry. Because the pairwise price-quantity is lacking for some food categories, the parametric constraints across demand equations (equation 7) cannot be applied, and each price equation of the demand system has to be estimated separately.

### Estimation Results

The estimation results by applying an autoregressive procedure (equation 8) with a specification of residuals lagged up to 2 years are contained in table 1. The quantity variables of food groups, the lagged residuals, and a constant term are listed across the top of the table, and the normalized price variables defined as the consumer prices deflated by the index of per capita income are listed down the left-hand side. For each pair of estimates, the upper part is the estimated price flexibility of a particular food category in response to the changes in group quantities, and the lower part is the estimated standard error.

In table 1, the estimated price flexibilities in each column can be used to assess how a change in the quantity of a specific food group, while holding the quantities of other groups fixed, affects the changes of all food prices. According to the estimates, for example, a marginal 1-percent increase in the quantity of red meats would reduce beef prices by 0.91 percent, pork prices by 1.42 percent, and prices of other meats by 0.27 percent. On the other hand, a marginal 1-percent increase in the quantity of poultry would reduce poultry prices by 0.84 percent.

Regarding the cross-quantity effects, an estimated cross-price flexibility between two food categories shows the percentage change in the amount consumers are willing to pay for one food when the quantity of another food increases by 1 percent. A negative cross-price flexibility means substitution, while a positive sign signals a complementary relationship between the two goods. This is because a marginal increase of the quantity of one good may have a substitution effect on other goods, and the price of other goods should be lower to induce consumers to purchase the same quantity of the other goods. For similar reasons, a positive cross-price flexibility means a complementary relationship.

**Table 1—Estimated price flexibilities, 1980-97**

Food category	Quantity						A(1)	A(2)	Const.	R <sup>2</sup>	D.W
	R.meat	Poultry	Dairy	Fru-veg	Starch	Other					
Price											
Beef	-0.9103 0.5804	-0.1463 0.3875	0.9731 0.7832	-2.228 0.5998	0.3930 0.4629	-1.5542 0.6856	-0.1730 0.2282	0.8288 0.1901	19.7644 3.7322	0.98	2.25
Pork	-1.4213 0.5191	-1.0333 0.3363	0.2833 0.6111	-0.5971 0.4300	0.4137 0.3796	-0.2665 0.5373	0.0083 0.2854	0.7127 0.2570	15.6813 3.1171	0.98	2.19
O. meat	-0.2662 0.4562	-0.4173 0.2646	0.2760 0.4570	-1.5301 0.2948	0.7003 0.2628	-1.0070 0.4266	0.2346 0.2830	0.7306 0.2495	14.0854 2.5691	0.99	2.25
Poultry	-0.3992 0.6098	-0.8367 0.3930	1.3397 0.7266	0.3317 0.4974	0.6789 0.4353	-1.8243 0.6241	0.0456 0.2672	0.7690 0.1976	6.9754 3.5818	0.98	1.81
Fish	0.4006 0.4645	-0.9340 0.2361	3.6906 0.4219	1.4430 0.2293	1.7932 0.2171	-3.8765 0.4154	0.9194 0.2796	0.5765 0.2835	-7.7412 2.6863	0.96	2.41
Eggs	-1.6583 1.5750	0.4597 0.8698	-4.6023 1.6411	-0.9403 1.0972	-1.8582 0.8885	0.8445 1.6114	0.2614 0.3579	0.4717 0.3622	38.7187 9.3285	0.95	2.05
Dairy	-0.1783 0.5139	-0.0538 0.2434	-0.8482 0.5009	-1.5566 0.2309	-0.1226 0.2180	-0.3093 0.4824	0.8725 0.3404	0.6772 0.3819	17.7182 3.1305	0.99	2.24
Fat-oil	-0.2304 0.2740	-0.0820 0.1571	0.4172 0.2823	-1.1413 0.1854	-0.4135 0.1603	-0.6658 0.2579	0.2503 0.1550	0.9355 0.0782	13.3481 1.5532	0.99	1.77
Fruits	-1.9234 0.6464	-0.6129 0.3728	-0.4895 0.6130	-1.0900 0.4234	0.8372 0.3618	0.8228 0.6043	0.1439 0.2185	0.7708 0.2307	14.6914 3.5118	0.91	1.84
Veget.	0.8952 0.3616	0.7380 0.1752	-1.8528 0.3180	0.0539 0.1641	-0.0475 0.1536	-0.8965 0.3221	1.0257 0.1930	0.8455 0.1727	8.3168 2.0949	0.94	1.53
Pro. F&V	-0.5765 0.3625	0.0285 0.1837	0.3798 0.3714	-0.0196 0.1880	-0.8083 0.1791	-1.3045 0.3426	0.8989 0.2909	0.5559 0.3090	14.0099 2.1740	0.99	2.57
Sugar	0.1189 0.3157	-0.3436 0.1978	0.6003 0.3910	-1.0903 0.2766	0.2854 0.2256	-0.8623 0.3394	-0.0094 0.2610	0.8353 0.2039	9.6658 1.9273	0.99	2.20
Cereal	0.6012 0.4674	0.4581 0.2260	-1.2757 0.3329	-1.2137 0.1852	-0.1140 0.1704	0.0186 0.3677	0.5964 0.3855	0.4646 0.4477	10.4283 2.5367	0.98	2.11
Beverage	0.1991 0.3253	-1.3034 0.1644	-0.0354 0.2756	-0.4102 0.1587	0.9869 0.1412	-0.2275 0.2909	0.7213 0.2574	0.6979 0.2801	7.4882 1.8378	0.99	2.03
Pre. food	-0.1502 0.2832	-0.2142 0.1817	-0.1900 0.4107	-0.4653 0.2908	-0.0003 0.2388	-0.5002 0.3686	0.3165 0.3595	0.1613 0.3671	10.4945 2.1118	0.99	2.11
Food away	-0.1099 0.1854	-0.2759 0.1759	0.5666 0.3012	-0.5129 0.3203	-0.1798 0.2185	-0.3626 0.3318	-0.6332 0.3317	0.5804 0.3343	7.5716 1.5418	0.99	2.37

Note: For each pair of estimates: the upper part is flexibility, and the lower part is standard error.

The notations are R. meat (red meats), Fru-veg (fruits and vegetables), Starch (starchy foods ), Const.(constant), O. meat (other meats), Veget. (fresh vegetables ), Pro. F&V (processed fruits and vegetables ), and Pre. food (prepared foods). A(1) and A(2) represent the autoregressive residuals lagged by 1 and 2 years, respectively, and D.W. represents Durbin-Watson statistics.

According to the estimates in table 1, for example, the cross-price flexibility of poultry with respect to the quantity change of red meats is -0.40 percent, and the cross-price flexibilities of beef, pork, and other meats with respect to the quantity change of poultry are -0.15, -1.03, and -0.42 percent. The negative values of these cross-price flexibilities suggest that red meats and poultry are substitutes. Many of the estimated cross-price flexibilities, however, are not statistically significant. This is probably because even though some individual foods either substitute or complement, aggregating different food items into a food category mitigates these cross-quantity effects. Also, annual data aggregates over seasons may contribute to the lack of statistical significance in some estimated cross-price flexibilities.

In addition, the residuals of the demand system are further specified as a second-order autoregressive process as suggested in equation 8. The estimation results are presented in the table under the columns of A(1) and A(2), which are estimated coefficients of autoregressive residuals lagged by 1 and 2 years, respectively. The estimates of goodness of fit ( $R^2$ ) in each price equation are satisfactory. All estimates of  $R^2$  are higher than 0.91, and in 14 of 16 cases the  $R^2$  is higher than 0.95. The Durbin-Watson (D.W.) statistics shown in the last column of the table suggest that the errors of each price equation are not serial correlated, and the estimated standard error is unbiased for use in a significant test of estimated price flexibilities.

To examine the possibility of improving forecasting performance by applying the autoregressive procedure (AUTO) rather than ordinary least squares (OLS), two indicators of performance are presented in table 2; one is  $R^2$  and the other is the root-mean-square percent error (*RMSE*). The *RMSE* of the *ex post* simulation is calculated as

$$RMSE = [ \sum_t (p_t - p_t^*)^2 / T ]^{1/2} / p \times 100$$

$$t = 1, 2, \dots, T \quad (9)$$

where  $p_t$  and  $p_t^*$  are respectively the actual and fitted normalized price levels for a sample period  $T$  years, and  $p$  is an average of actual normalized price levels. The *RMSE* expressed as a percent error of sample mean can be used for comparison across the price equations, because each *RMSE* is independent of the magnitude of each price index series, which ranged from 130 percent for nonalcoholic beverages to 236 percent for fresh fruits in 1997.

According to the estimated indicators in table 2, the estimates of  $R^2$  in the AUTO case are uniformly higher than those of OLS, especially for cases like fresh fruits, which increased from 0.81 to 0.91, and fresh vegetables, which increased from 0.74 to 0.94. Regarding estimated *RMSEs*, most of the estimates of AUTO are smaller than those of OLS, except for cereal and other prepared food categories with slightly higher estimates. The measures of *RMSE* for the AUTO model range between 0.37 and 1.98 percent, while the measures for the OLS model range between 0.38 and 2.03 percent.

On the basis of estimated  $R^2$  and *RMSE*, as expected, the application of an autoregressive model yields significant improvement in forecasting performance. The conformity of the fitted prices with the sample observations by using the AUTO model appears reasonably good. These results provide evidence that the estimated parameters adequately reflect food price responses to changes in quantity and income over the sample period. Therefore, for the purpose of price forecasting, the estimates of the autoregression model contained in table 1 should be used.

To clarify the forecasting results over the sample period, the fitted normalized prices from the estimated model are further transformed into Consumer Price Indexes. To get a close look at the accuracy of fitted prices, a comparison of actual and fitted food prices over the years 1995, 1996, and 1997 are presented in table 3. The errors of prediction are within 5 percent for most cases; in particular, all the errors of prediction in 1997 are within 3 percent. In addition, the turning-point errors over the whole sample period 1980-97 are listed in the last column of the table. The number of turning-point errors among 17 observed changes is equal to 5 errors or less in 13 cases out of 16 price forecasts. Graphic comparisons of actual and fitted results are presented in appendix A. This graphic presentation provides additional information about forecasting performance.

To facilitate the application of the price-forecasting model, a spreadsheet model was developed for an automated simulation of food prices. Users are required to provide input data about the concerned per capita quantity of food consumption and per capita income. The simulation results expressed in logs of normalized prices that is  $\log(p_t / m_t)$  at year  $t$ , are generated first. Then all forecasts of normalized prices are transformed into price index levels.

**Table 2—Comparison of autoregressive and ordinary least square results**

Food category	R <sup>2</sup>		RMSE	
	AUTO	OLS	AUTO	OLS
Beef and veal	0.98	0.97	0.99	1.31
Pork	0.98	0.98	0.76	0.80
Other meats	0.99	0.99	0.60	0.73
Poultry	0.98	0.96	0.90	1.08
Fish and seafood	0.96	0.94	0.63	0.72
Eggs	0.95	0.94	1.98	2.03
Dairy products	0.99	0.99	0.65	0.78
Fats and oils	0.99	0.99	0.40	0.76
Fresh fruits	0.91	0.81	0.74	0.97
Fresh vegetables	0.94	0.74	0.50	0.92
Pro. fruit & veget.	0.99	0.98	0.52	0.69
Sugar and sweets	0.99	0.99	0.49	0.66
Cereals and bakery	0.98	0.98	0.42	0.40
Beverages	0.99	0.99	0.41	0.52
Prepared foods	0.99	0.99	0.43	0.40
Food away from home	0.99	0.99	0.37	0.38

Note: The notations are R<sup>2</sup> (R-squared), *RMSE* (root-mean-square percent error), AUTO (autoregressive procedure), and OLS (ordinary least squares).

**Table 3—Forecasting performance**

Food category	1995			1996			1997			Turning point error
	Actual (1)	Predict (2)	Error percent	Actual (1)	Predict (2)	Error percent	Actual (1)	Predict (2)	Error percent	
Beef	134.9	133.0	-1.39	134.5	140.1	4.15	136.8	137.6	0.56	3
Pork	134.8	140.1	3.90	148.2	145.7	-1.70	155.9	155.4	-0.31	1
O. meat	139.0	140.5	1.06	144.0	145.3	0.94	148.1	146.1	-1.36	2
Poultry	143.5	142.8	-0.46	152.4	150.9	-0.98	156.6	157.2	0.36	7
Fish	171.6	159.9	-6.83	173.1	181.2	4.70	177.1	176.6	-0.28	4
Eggs	120.5	131.7	9.31	142.1	127.2	-10.46	140.0	144.1	2.92	4
Dairy	132.8	138.2	4.04	142.1	138.8	-2.31	145.5	144.3	-0.80	6
Fat-oil	137.3	138.5	0.89	140.5	140.5	-0.02	141.7	140.5	-0.81	4
Fruits	219.0	223.1	1.88	234.4	232.3	-0.88	236.3	234.9	-0.60	1
Veget.	193.1	185.6	-3.87	189.2	194.7	2.93	194.6	193.3	-0.65	5
Pro. F&V	137.5	139.9	1.76	144.4	142.7	-1.17	147.9	148.7	0.54	7
Sugar	137.5	138.9	1.00	143.7	144.7	0.70	147.8	146.0	-1.19	3
Cereal	167.5	170.8	1.95	174.0	171.6	-1.36	177.6	177.7	0.06	0
Beverage	131.7	130.8	-0.65	128.6	131.2	2.02	133.4	130.6	-2.12	5
Pre. food	151.1	151.3	0.13	156.2	155.8	-0.29	161.2	162.1	0.57	1
Food away	149.0	149.5	0.31	152.7	155.6	1.88	157.0	159.5	1.57	1

Note: The notations are O. meat (other meats), Veget. (fresh vegetables ), Pro. F&V (processed fruits and vegetables ), and Pre. food (prepared foods). Error percent is calculated as  $[(2) - (1)] / (1) \times 100$ .